

Transient EM Response Characteristics of Three-dimensional Fracture Models Based on Rock Physics Information

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SUMMARY

Hydraulic fracturing is an essential technical means for unconventional oil and gas development, and hydraulic fracturing monitoring is the core technology to accurately evaluate the effect of hydraulic fracturing and reservoir transformation. Electromagnetic (EM) exploration method has unique advantages in the identification of fluid electrical characteristics, especially the high-power long-wire transient EM method, which has the outstanding advantages of large detection depth and low cost, and has become a research hotspot in the field of hydraulic fracturing monitoring. However, the target area of hydraulic fracturing is mainly composed of fractured media with large buried depth, and obvious anisotropy, so it is difficult to achieve accurate modeling for EM responses by conventional transient EM forward simulation algorithm.

In conventional EM forward modeling, the influence of rock composition and micro-structure on EM responses is often neglected. However, the rock physics information is crucial for evaluating the extent of fracture development and the direction of hydraulic fracturing fluids. Therefore, it is a prerequisite for modeling the high-precision transient EM responses for the fracturing earth model, using macroscopic equivalent medium models with the consideration of the micro-fracture media physical properties. Additionally, during the hydraulic fracturing process, different stress directions on the fractures will cause varying degrees of development along different directions. When the scale of the fracturing layer is large enough or multiple fracturing accumulates, it will result in apparent anisotropic characteristics in the macroscopic formation. Therefore, it is necessary to study the characteristics of transient EM responses in anisotropic media conditions during the process of hydraulic fracturing monitoring.

In this paper, firstly, we conducted theoretical modeling for the fractured media using a dual-porosity medium model and analyzed the anisotropic characteristics of reservoir rock samples from the tight shale of the Wufeng Formation pre- and post- processes. Secondly, based on the electrical model of fractured media, we built a macroscopic electrical model that considers the electrical parameters of fractured rocks, and adopted the three-dimensional spectral-element EM forward modeling method to calculate the transient EM response. And then, we achieved the identification of the EM signals in the target area of hydraulic fracturing. Our modeling example demonstrates that, 1) the post-fracturing EM signal is significantly different for the isotropic and anisotropic fracture models, and 2) the difference values of EM signals between the pre- and post-fracturing for the anisotropy model has a stronger ability to identify the fracturing zone. Finally, our study provided a theoretical reference for the analysis of transient EM data in the fracturing monitoring area.

Keywords: Forward modeling, Fracture model, Transient EM, Hydraulic fracturing monitoring
